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ORIGINAL RESEARCH

Inequalities in Health: Definitions, Concepts and Measurements—An Application in the Regional Health Authority in Italy

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Abstract

Policymakers, researchers, and public health practitioners have long sought not only to improve overall population health but also to reduce or eliminate differences in health based on geography, race/ethnicity, socioeconomic status, and other social factors. Italian healthcare authorities and health policy makers are called to help to both solve existing inequities in accessing healthcare and remove barriers to healthcare. In this context, COVID-19 has highlighted the aspect of inequalities. Our paper proposes an overview of different methods of measuring health inequalities and their applications, both in regional and national contexts, in absolute and relative scales. The first involves an application on accessibility to an obstetrics clinic in a district of Marche region, connected to the educational level of the female population. The second, calculates the indices on inequalities in the infant mortality rate in the Italian regions in relation to income. Finally, the three indices are calculated considering the rate of self-perceived health in relation with the GDP per capita. To achieve this goal, we use the Kuznets index, the slope index of inequality and the concentration index as measures of social inequalities. The measurement of health inequities is an excitingly multidisciplinary endeavor. Its development requires interdisciplinary integration of advances from relevant disciplines. The proposed approach is one such effort and stimulates cross-disciplinary dialogues, specifically, about conceptual and empirical significance of definitions of health inequities.

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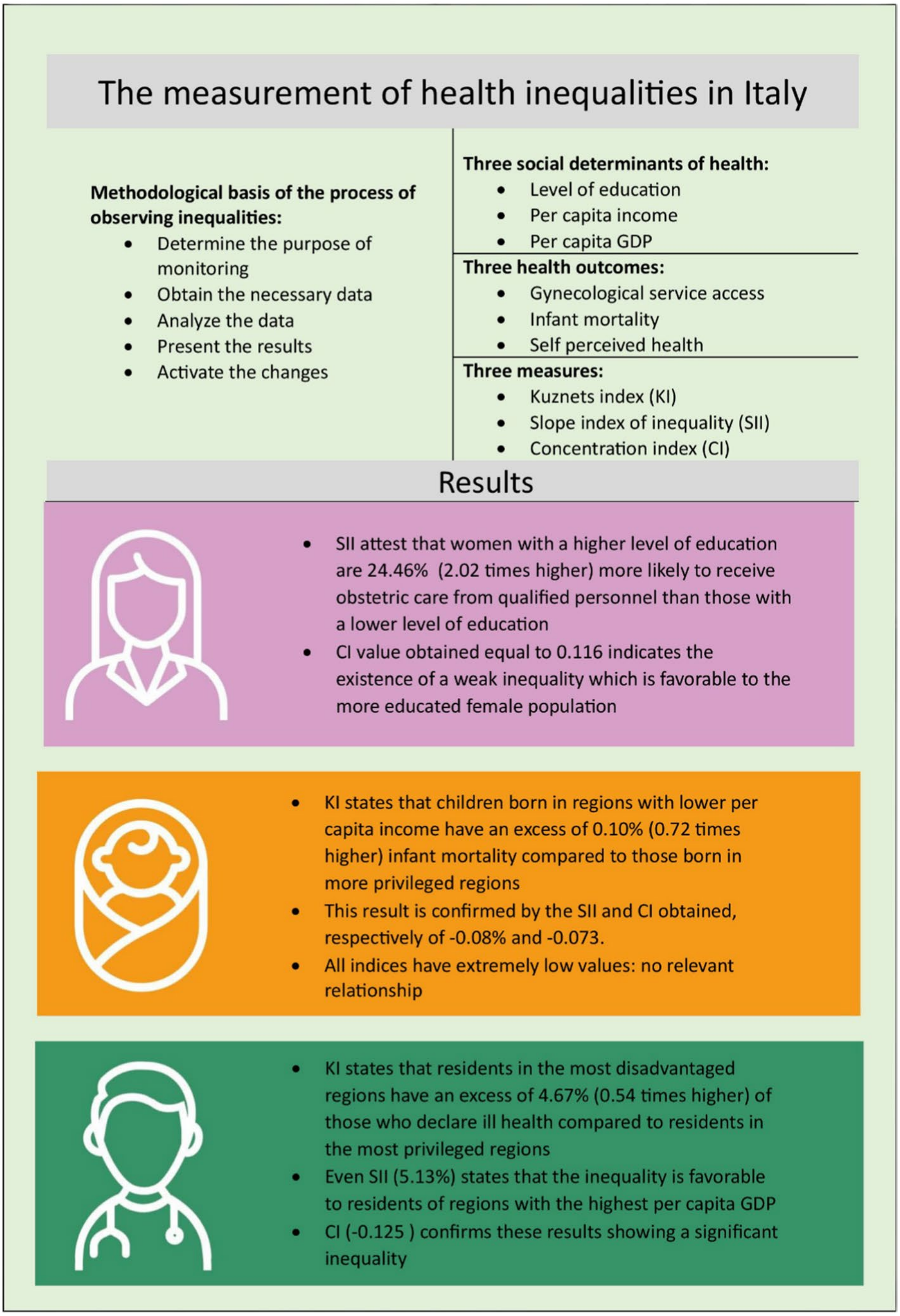
Graphical Abstract



Keywords Health care · Health status · Health inequalities · Social determinants of health · Composite index · Summary measures of health inequalities

1 Introduction

In Italy, as in some other countries, health improvements have slowed in recent years and have been far from uniform (Bruzzi et al., 2022). There are large and, now deepening inequalities in health, closely linked to inequalities in the social determinants of health. The greater the social disadvantage the shorter the healthy life expectancy. So marked are these inequalities that for groups at greater disadvantage, health has stopped improving or is even getting worse. All of this was exacerbated by the COVID-19 pandemic (Bibby et al, 2020). Because many of these health inequalities could reasonably be reduced or eliminated, their existence is unfair. We call these inequities.

The term health inequality generically refers to differences in the health of individuals or groups (Arcaya et al, 2015). Any measurable aspect of health that varies across individuals or according to socially relevant groupings can be called a health inequality. Absent from the definition of health inequality is any moral judgment on whether observed differences are fair or just. In contrast, a health inequity, or health disparity, is a specific type of health inequality that denotes an unjust difference in health. By one common definition, when health differences are preventable and unnecessary, allowing them to persist is unjust. In this sense, health inequities are systematic differences in health that could be avoided by reasonable means. In general, social group differences in health, such as those based on race or religion, are considered health inequities because they reflect an unfair distribution of health risks and resources. The key distinction between the terms inequality and inequity is that the former is simply a dimensional description employed whenever quantities are unequal, while the latter requires passing a moral judgment that the inequality is wrong.

As early as the nineteenth century, the impact of social factors on health was identified (Berghmans, 2009). In particular, the state of health and life expectancy of individuals differ according to their social status. Social inequalities in health do not relate to the genetic or physiological differences of individuals, which are normally defined as health inequalities. Social health inequities, instead, refer to external social factors such as income, type of work, level of education, sex, cultural level, membership of a racial group or sexual orientation. These inequities cross the whole society according to a continuum. The more socially-favoured you are, the longer your life expectancy will be and the better your chance of being healthy. In Italy, for example, a 35-year-old worker has a life expectancy of about 5 years less than that of a manager (Ardito et al., 2022). Furthermore, using methods to measure income-related health inequalities, some studies reported substantial inequities unfavourable to low-income groups (Abbas et al., 2019; Hafeez et al, 2023; Mangalore et al., 2007; Moreno et al, 2020). However, the terms inequity and inequality are used interchangeably in this article, referring to both kinds of difference.

The COVID-19 pandemic highlighted and aggravated social problems and related inequalities and has revealed social and territorial inequalities in health (Febvel, 2020). COVID-19 brought a greater toll to groups already suffering from poor health; including some ethnic communities and people who live in areas with a higher deprivation index (Shoib et al., 2021; Townsend et al., 1988). Since March 2020, Italy has implemented various containment measures, including community quarantine, self-isolation, and social distancing; with differences existing in the practices across regions in Italy due to their specific situation related to the number of cases reported, social and economic development levels, etc. These measures, together with the economic impacts of the partial shutdown of the economy, accentuated the mental health problems of the affected population.

Consequently, the National Health Service (NHS) in Italy must face new challenges by doing its utmost to reduce inequalities in coming years (Franci et al., 2018). Furthermore, the NHS and the National Plan for Reconstruction and Resilience (PNRR) have a vital role in adopting investment policies aimed at prevention and must be dedicated to reducing inequalities in access to services. In summary, reducing inequalities should be a key aspect of the PNRR. It will have to promote integration between services, stimulating new forms of collaboration between the NHS, local governments, and voluntary associations. The reduction of inequalities and the improvement of health for all will represent, in the medium and long term, a challenge for the World Health Organization (WHO), for the Italian regions, and for all bodies and organisations that are active in the health sector.

It is now evident that monitoring average achievement is no longer considered a sufficient indicator of a country's progress on the health front. It is apparent that the extent of inequality in the distribution of health across the population subgroups is a complimentary key imperative piece of information in a country's NHS. This requires researchers to investigate a fundamental question of how to monitor health inequalities.

For the above considerations, the measurement and the monitoring of health is essential for advancing with equity toward sustainable development. Numerous research (Asada, 2005; Pampalon et al., 2009; Coulter, 2019; McCartney, 2019; Kunonga et al., 2023) presented various social dimensions and measures to quantify inequalities in health. However, currently, there is no consensus on a standard measure, more informative than the gap measure, that can be routinely part of the NHS data to alert countries to inequalities in health and identify the priority health inequality conditions.

Therefore, trying to contribute to the literature on the methods of inequalities measurement and their applications, the principal aims of our study are:

(1) To underline the importance of the conceptual model of health proposed by the WHO, elaborated by the Commission on Social Determinants of Health.
(2) Check if the features of this model can provide a logical basis for measuring and monitoring health inequalities.
(3) Use some indices for measuring inequalities that can make a valid contribution by enabling real understanding of the phenomenon.

2 Conceptual Basis for Measuring and Monitoring Health Inequalities

A model that is well suited as a conceptual and theoretical basis for measuring health inequalities is that of social determinants of health (SDOH) proposed by a specific commission and implemented by the WHO in its final report of 2007 (Fig. 1). Social determinants of health are the nonmedical factors that influence health outcomes. They are the conditions in which people are born, grow, work, live, and age, and the wider set of forces and systems shaping daily life. These forces and systems include, but are not limited to, economic policies and systems, development agendas, social norms, social policies, racism, climate change, and political systems

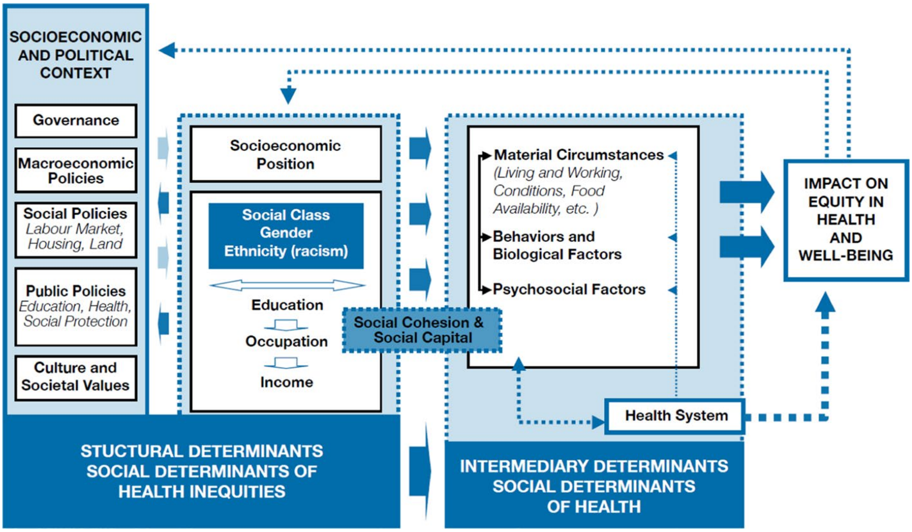


Fig. 1 The structural determinants and the intermediary determinants of inequalities in health. Solar and Irwin's model adopted by the WHO commission on social determinants of health

This conceptual model is inspired by a series of previous models, namely the well-known model of Dahlgren and Whitehead (1991) and the Social Production of Health by Diderichsen and Hallqvist (1998). In Solar and Irwin's model (Solar and Irwin, 2007), the social position plays a crucial explanatory role. Social position is a construct capable of capturing an ecological characteristic of any social organisation. All this happens through the social gradient, which refers to the hierarchical organisation of the members of society. Social position is represented by income, education, occupation, gender, ethnicity, and environment. There are also dimensions that represent proxy variables of the SDOH. According to this conceptual model, the social position determines the distribution of the health and well-being of the population, which is in turn mediated by the intermediary determinants that include material circumstances, social cohesion, human behaviour, genetic predisposition and necessarily the organisation of the health services system.

Social position is influenced by the "distal determinants" which Marmot, paraphrasing Rose (1985), rightly calls "causes of causes" or "structural determinants". These impact, through the intermediary determinants of health, outcomes.

In line with the model of SDOH, the literature (King's Fund, 2020; Heaslip et al., 2022; Renzi et al., 2021) considers the eco-epidemiological paradigm which, recognising the existence of multiple organisational levels, forms a coherent structure for understanding and explain the observed reality. It provides a guideline for public health policies and proposed interventions to improve the current situation.

In addition, five other supporting arguments can be introduced to conceptualise the measurement of health inequalities.

- The concepts of "health inequalities" and "SDOH" are inextricably linked. Therefore, health inequalities can only be eliminated through action on the determinants of health.

- Inequalities in health are a consequence or effect of social inequalities.
- Injustices in health cannot be measured with scientific rigour. Instead, it is possible to measure inequalities in health, since they are defined as differences in health found between two or more population groups. Using ethical judgment, injustices can be inferred from observed inequalities.
- It is impossible to set thresholds or benchmarks for injustices. It is the task of every society and every historical period to define what is considered harmful to the sense of social justice.
- The identification of health inequalities represents an important aspect which must be accompanied by contrasting and resolving actions to remedy this unjust situation.

3 Data and Methods

There are various approaches to studying inequalities within and between populations. Most commonly, we examine differences in health outcomes at the group level to understand social inequalities in health. Alternatively, it is possible to focus on health differences across individuals, for example, describing the range or variance of a given measure across an entire population. It can also be useful to compare outcomes across individuals within a single country.

In our analysis we made use of the data reported from database of an obstetrics clinic in a district of an Italian region for the year 2016 and from the National Institute of Statistics (ISTAT) for the years 2017 and 2018.

In this section, geographic and wealth-related health inequalities in Italy were measured as an illustrative practical example. A literature review was conducted to understand the health inequality measures and their use (Asada et al., 2014; Dagenais, 2019). Our study was conducted in 5 steps. They are in order:

1. Determine the purpose of monitoring.
2. Obtain the necessary data.
3. Analyse the data.
4. Present the results.
5. Activate the changes.

At each step of this cycle, professionalism, resources, and skills are required to ensure rigorous processes are followed and that fair, effective, and corrective outcomes are proposed. Monitoring inequalities in key health-related areas is a useful procedure for strengthening health policies and enabling their development.

Within a framework rich in contributions (Braveman, 2006), it is possible to identify guidelines for measuring social inequalities in health. One way to achieve this is to go through the identification of three key components (Fig. 2):

1. an indicator of health.
2. an indicator of social position.
3. From the intersection of these sets of indicators one gets: a measure of inequality.

The three elements can be well displayed in the following scheme:

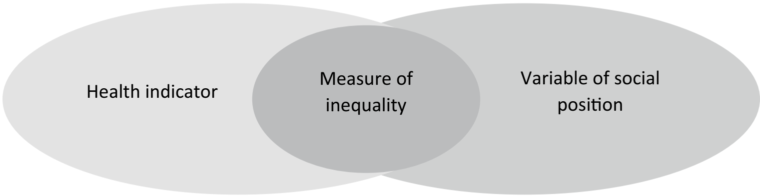


Fig. 2 The 3 key components to measure health inequalities

Table 1 First key component: some examples

Example areas linked to health inequality	Determinants of health
Health status (life expectancy and the prevalence of certain health conditions) Accessibility to care Quality and care experience Perception of health status …	Behavioural risk factors (smoking, passive exposure to smoke, physical activity, etc.) (Su et al., 2021) Nutrition (fruit and vegetables, sugary drinks, junk foods, etc.) (Zafar et al., 2022) SDOH in broad sense (quality and costs of accommodation, food insecurity etc.) …

Table 1 presents example of health indicators and determinants, which represent the first key component of inequality.

The methodological approach underlying the measurement of inequalities and the monitoring of its flows, is based on the concept of the SDOH, which has the social position of individuals as its main characteristic. This is reflected in the distribution of health and well-being in the population. Essentially, our method develops in the following lines:

- The first follows an axiomatic approach, according to which the state of health is compared between two or more groups of the population.
- The second expresses this comparison with a standard and summary metric of health inequality.
  - This can concern both the difference in the state of health between two social groups (usually the two opposite extremes),
  - The analysis of the gradient, that is, computing the extent of health inequalities between the entire social hierarchy.
  - The expression of either an absolute value (i.e., in the same unit of measurement as the health variable) or a relative value (through a dimensionless measure) capable of quantifying the existing gap.

From an operational point of view, our methodology can be divided into three phases, which are based on a set of available data capable of capturing three distinct basic dimensions: social, demographic and health.

Once you have identified the division of the population into groups, the next step will be to select a health indicator. Finally, appropriate and summary measures will have to be identified to measure inequality within the various subgroups.

Table 2 represents, in a broad way, the social variable (a second key component for the measurement of inequalities), which normally contains proxies of social determinants. These will be used to reproduce the social hierarchy in the analysis to be conducted. The demographic variable will be used to size social groups. Finally, the health variable will

Table 2 Second key component: some examples (ISTAT, 2015)

Socio-economic status by income quintile: 1st quintile (poorest); 2nd quintile; 3rd quintile; 4th quintile; 5th quintile (the richest)
Education level: no education level; Primary School; secondary or higher
Employment: classification of professions into 9 groups according to ISTAT: 1. Legislators, entrepreneurs and senior management; 2. Intellectual, scientific and highly specialized professions; 3. Technical professions; etc
Employment status: employed or unemployed
Place of residence: urban or rural
Age: age groups according to ISTAT
Gender: male or female
Regions: large areas
…

be used to analyse in detail how it is distributed between the identified groups. The above considerations clearly highlight the three fundamental steps that must be taken to achieve what has been asserted, namely:

(1) Reproducing the social hierarchy or creating a scale that focuses on the social position of the groups.
(2) Analyse the distribution of health within the constructed social scale.
(3) Calculate a standard metric to quantify health inequality within the identified groups.

Faced with this exposition, it can be said that the methodology adopted, assumes the centrality of social position, because it will be able to explain and quantify the production of health inequalities among populations. These reflections are schematised in Fig. 3 and in the related Table 3, where the three indices capable of conceptualising the analytical approach are identified.

They show the three index values, which will be used to analyse the health inequality of a population sorted by social position. In Fig. 3, the cumulative proportion of the population ordered by a socio-economic variable is shown on the horizontal axis (for example: per capita income, per capita GDP, level of education, etc.). The ordinate, on the other hand, indicates the distribution of the health variables in the groups. It is important to note that these three indices are not mutually exclusive.

In fact, the first option provides for the subdivision of the population into quantiles (usually quintiles) calculated for the socio-economic variable chosen. Subsequently, it will be necessary to evaluate, using the Kuznets index, the distribution of the health indicator within the groups thus created.

The other two options refer either to the use of a regressive model (calculating the *Slope Index of Inequality (SII)),* or through the construction of a concentration curve (calculating the *CI).* These last two options prove to be methodologically more sophisticated, but also more precise.

As regards the calculation of the CI, the literature suggests various approaches, depending on whether the population is divided into groups or organised in single statistical units. In the first case, two versions of the calculation of the CI can be used, which

Population ordered by social hierarchy (ordered classification of the population according to a social determinant of health, for example per capita income, per capita GDP, level of education, etc.). In this case, a ranking of the population will be indicated on the abscissa, starting from a more disadvantaged position up to a more privileged one.

Additional social determinants of health that can be considered as stratifiers:

Place of residence — **Religion**
Ethnicity / Race — **Occupation**
Share capital — **Gender**
Social capital of the population

Fig. 3 Analytical bases for measuring health inequalities

are little known in the literature, namely those proposed by Brown (1994) and by Fuller and Lury (1977). In the second case, instead, one should proceed with the integral calculation ($C = 1 - 2\int_0^1 L_h(p)dp$ where $\int_0^1 L_h\ (p)dp$ represents the area below the concentration curve) of the CI according to the hypothesis of Wagstaff and van Doorslaer (1991).

3.1 Kuznets Index (KI)

Kuznets has particularly focused on economic growth and income inequalities between the wealthiest and least wealthy classes. He is known for having elaborated the so-called *Kuznets curve* (1955) which describes the trend of inequality in relation to the rate of development, showing the evolution of the income distribution over time.

The Kuznets index, due to its peculiarities, is also suitable for the measurement of economic inequalities as they relate to health. In fact, following his approach, the population under study is grouped into percentiles (in our case in quintiles) with respect to the chosen indicator, sorted from the most disadvantaged to the most advantaged group. Based on these observations, two methods of calculating this index are suggested: the absolute and the relative. In the first case, a mere difference is calculated between the health indicators measured in the extreme quantiles (e.g., first and fifth quintiles) of the population. In the second case, instead, the ratio between the same indicators is envisaged.

Table 3 Main measures for calculating health inequalities in macro and micro areas

Summary measures	Description	Socioeconomic size of the population used to identify its gradient
1. Kuznets index	Provides for the subdivision of the population sorted by socio-economic variable in quintiles. An absolute and relative version is known. The absolute version shows the difference in the estimated health indicator between the two population subgroups, i.e., the most disadvantaged and the least disadvantaged The relative one involves the calculation of the ratio between the two values of the indicator in the two subgroups indicated above	Economic status
2. Slope index of inequality	It measures the difference between the values of a socio-health indicator calculated between the most advantaged and the most disadvantaged social groups. There is also a relative version calculated through the ratio between the values of the indicator mentioned above	Economic status, level of education
3. Concentration index	Relative measure of inequality. Commonly applied in the field of health economics to show the degree to which a health indicator is focused on the most advantaged or least advantaged group	Economic status, educational level

3.2 Slope Index of Inequality (SII)

This index measures the difference between the values of a socio-health indicator for highest and lowest social group of a socially ordered hierarchy (typical examples are the level of education, the wealth index, level of unemployment, etc.) (Pamuk, 1985).

The index is estimated using a regression model, where a socio-economic measure is the independent variable, and the indicator of health is the dependent.

The application could concern a linear model, in the hypothesis with a continuous variable, or a logistic model in the hypothesis with a dichotomous or binary variable.

The angular coefficient resulting from the simple linear regression analysis will reveal an estimated difference in health between the socially most advantaged and the most disadvantaged population.

Further examples of this method can also be observed in the deprivation index (Fabbris & Sguotti, 2013), starting with the individual who has a worse index towards the one who has a better one. In this hypothesis, positive SII values are predictors of a better state of health found in the less deprived population. Conversely, its negative value will reveal a worse state of health observable in the less deprived population.

Finally, its value equal to 0 will be indicative of a perfect equality found within the social gradient observed in the population under study.

The literature (Moreno-Betancur et al., 2015) also proposes a relative version of the SII. In this case, its quantification will take place by calculating the ratio between the two estimated values at the two ends of the distribution.

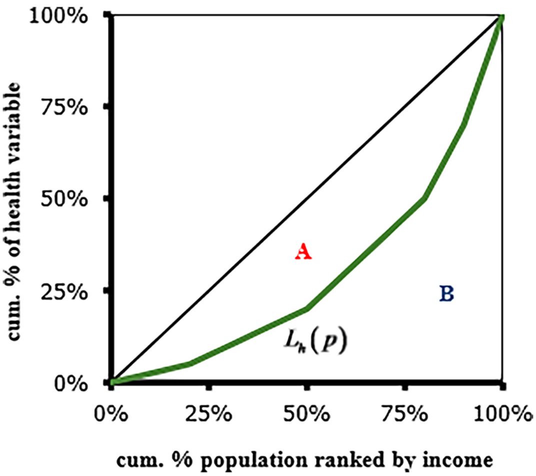


Fig. 4 The concentration curve for health. *Source*: Wagstaff et al. (2007)

3.3 Concentration Index (CI)

It is widely established (Marmot, 2008; Marmot et al., 2020) that the SDOH act predominantly on the state of health of populations, with income representing one of the important determinants. The Lorenz curve and the Gini concentration ratio have proved to be effective tools for quantifying inequalities. However, in the field of health, they turn out to be insufficient since both use a single variable both for the sorting of the population and for the measurement of concentration. To overcome this obstacle and link the state of health to the socio-economic dimension, new index called the CI has emerged in the literature.

It is considered one of the standard tools for measuring socioeconomic inequalities in health (Wagstaff et al., 2007) so much so that it is widely used to measure and compare the level of income-related health inequalities between different countries and between different strata of the population, (Wagstaff, 2000). Further applications of this index have examined the relationship between socioeconomic inequalities and mortality, specifically infant mortality. Still others have focused on inequalities related to access to health and social services (Bryce et al., 2003).

The CI is a relative measure of inequality that indicates the degree to which a health indicator is concentrated on more or less privileged groups of the population. It is a bivariate measure of inequality and differs from the Gini index and the Lorenz curve, since the variable on which the population is sorted and the health variable of interest are different from each other (van Doorslaer et al., 2004).

For its visualization, the index starts from the Lorenz curve. Therefore, its value is defined as double the area between the effective concentration curve and the line of equality (at 45°). By convention, the index assumes a negative value when the curve lies above the line of equality and positive when it lies below (Fig. 4). In other words, the CI assumes a negative value when the health indicator is concentrated among the most disadvantaged people from a socio-economic point of view. Conversely, it will assume a positive value in the hypothesis that the same health indicator is concentrated among the most privileged people.

From these simple considerations it is concluded that the CI has a range of variation between -1 and + 1, that is:

$$-1 \leq \text{CI} \leq +1$$

Therefore, the value -1 corresponds to the situation where the health indicator under study it is concentrated on the most disadvantaged individual. While the evaluation of + 1 corresponds to the opposite case in which the health indicator is concentrated in the most privileged person. The index can also assume a value equal to 0. In this case it highlights a situation in which there is no inequality or when the sum of the subtended areas above and below the bisector, taken with their relative sign, is equal to 0.

From a geometric point of view, the CI inferable from Fig. 4 is defined as follows: $CI = \frac{A}{A+B}$

Since the area (A + B) is equal to 1/2, then CI = 2A which can also be written in the following alternative form CI = 2 (1/2−B) = 1−2B.

3.4 Method for Calculating the CI for Populations Divided into Groups According to Brown's Method

The calculation of the CI is much easier if it is possible to divide the population under consideration into groups, ordering them by the socio-economic variable. In this case there are different methods of calculating the CI, but a simple and little-known formula is the one suggested by Brown, who has had several applications in the international field in the evaluation of health inequalities (Berndt et al., 2002; Brown, 1994). The formula for its calculation is the following:

$$G = \frac{A}{A+B} = \frac{A}{\frac{1}{2}} = 2A = 1 - \sum_{i=0}^{k-1} \left(Y_{i+1} + Y_i\right)\left(X_{i+1} - X_i\right)$$

where k is the number of survey points and X and Y are the coordinates of the points on the graph. The result of this formula can be easily calculated using a spreadsheet.

Therefore, the first step in calculating the CI, using Brown's formula, for aggregated data at a geopolitical level, is to sort the groups according to the socioeconomic variable, starting from the worst condition and moving towards the best. The proportions for the population and health variable are then noted. The cumulative proportions for the two variables are then calculated. The graph showing the cumulative proportion of the health variable (Y axis) and the cumulative proportion of the population sorted by socioeconomic variable (X axis), can be used to calculate the CI. This measure lends itself well to a comparative interpretation under study or to compare the value under study with that found in other geographical areas or for its evolution over time.

3.5 Method for Calculating the CI for Populations Divided into Groups According to the Fuller and Lury Method

Another formula for calculating the CI for a population divided into groups ordered by a socioeconomic variable is the one proposed by Fuller and Lury (1977). Also, in this case the index can be easily calculated with the use of a spreadsheet.

$$CI = \left(p_1L_2 - p_2L_1\right) + \left(p_2L_3 - p_3L_2\right) + \ldots + \left(p_{T-1}L_T - p_TL_{T-1}\right)$$

where p_t represents the cumulative percentage of the sample classified by socioeconomic status for group t, L_t corresponds to the value of the cumulative health measure for group t (Wagstaff et al., 2007).

4 Results and Discussion

We now illustrate the application of the three indices described above in three distinct scenarios. The first involves an application on accessibility to an obstetrics clinic in a district of an Italian region; and is connected to the educational level of the female population. The second will calculate the indices on inequalities in the infant mortality rate in the Italian regions in relation to income. Finally, the three indices will be calculated considering the rate of self-perceived health in relation with the GDP per capita.

4.1 Scenario One: Calculation of the Indices for the Female Population of an Obstetrics Clinic Classified by Level of Education

In this first application we calculate the SII and CI on data collected in an obstetrics clinic belonging to a district of an Italian region. The socioeconomic variable used to order populations, represented by the number of resident women, is the level of education (Balaj et al., 2021) while accessibility to the service was used as a socio-sanitary variable, through the number of obstetrics visits carried out. The data used refer to the year 2018.

4.1.1 Calculation of the SII on the female population of an obstetrics clinic

Table 4 presents the procedure for calculating the SII and for producing the relative graphs.

The graphical representation shows the expected value of a health problem (in this case receiving obstetric care from highly qualified personnel) as a function of the cumulative proportion of females sorted by level of education (Fig. 5).

The percentage value estimated in the reception of an obstetric need (given by a qualified professional) is found among females with the lowest level of education (rank = 0). It is equal to 23.9%. Conversely, among females who have the highest education (rank = 5), this estimate stands at 48.36%. Therefore, the SII will be obtained from the difference between 48.36 and 23.9% = 24.46%.

The result of the SII obtained attests that women with a higher level of education are 24.46% more likely to receive obstetric care from qualified personnel than those with a lower level of education.

Finally, a relative measure of this index can be estimated by calculating the ratio between the two values calculated at the two ends of the distribution. This relative scale index, therefore, will be: 48.36%/23.9% = 2.02. In this case it can be said that the reception of obstetric care is 2.02 times higher within the more educated female group than the less erudite one.

Table 4 Classification of the female population by level of education and by number of obstetric visits received by a gynaecologist (repeated visits were counted once). Source: our survey on a health district

Level of education	Number of women F_d	f_{rd}	f_{rd} *cum*	Number of visits F_v	%
elementary	600	0.12	*0.12*	185	*30.83%*
lower average	863	0, 17	*0.28*	271	*31.40%*
upper average	1695	0.33	*0.61*	526	*31.03%*
bachelor’s degree	1212	0.23	*0.84*	459	*37.87%*
master’s degree	821	0.16	*1.00*	476	*57.98%*
Total	5191	1		1917	

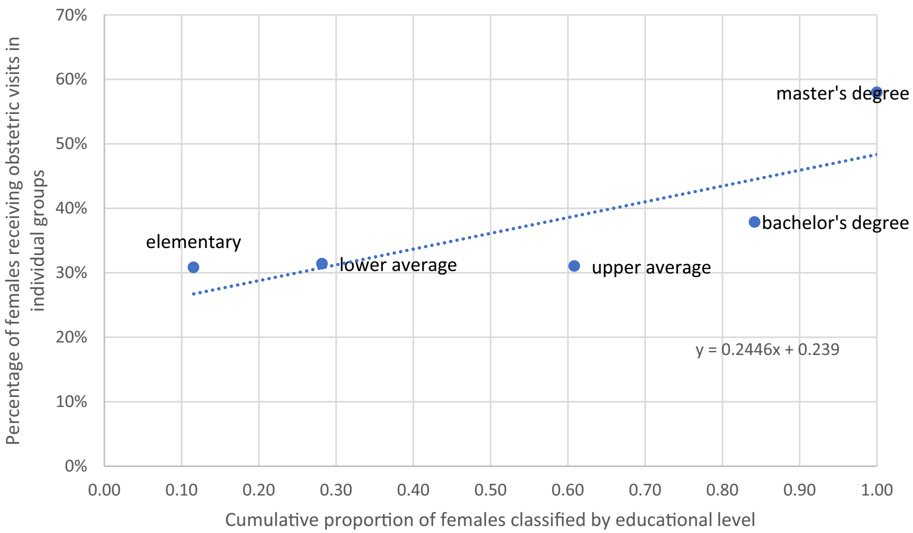


Fig. 5 Index of inclination of inequalities for obstetric needs according to the level of education

4.1.2 Calculation of the CI on the female population of an obstetrics clinic using the Brown and the Fuller and Lury formulas.

The steps for calculating the CI and the graphical representation of the concentration curve are as follows:

(1) Sort the population groups in ascending order based on the socio-economic variable chosen (education level).
(2) Calculate the number of visits for each group.
(3) Calculate the relative frequency of the number of women and the relative frequency of visits.
(4) Calculate the cumulative relative frequencies for both variables.
(5) Calculate the CI using Brown's formula and Fuller's and Lury's formula.
(6) Graph the concentration curve, placing the cumulative frequency of the population (number of women) on the X axis and the cumulative frequency of the health variable (number of visits) on the Y axis.

Table 5 presents the procedure for calculating the CI and for producing the relative graph.

The two columns in italic in the table are suitable for dual use:

1. to calculate the *CI*.
2. to construct the concentration curve (see Fig. 6).

The CI value obtained equal to 0.116 indicates the existence of a weak inequality which is favourable to the more educated female population (calculated CI values hardly exceed 0.5, while values between 0.2 and 0.3 identify relatively elevated levels of inequality).

Table 5 Classification of the female population by level of education and by number of obstetric visits received by a gynaecologist and calculation of CI (Repeated visits were counted once)

Education level	Number of women F_d	f_{rd}	f_{rd} *cum*	Number of visits F_v	f_{rv}	f_{rv} *cum*	CI Brown	CI Fuller and Lury
elementary	600	0.12	*0.12*	185	0.10	*0.10*	0.011	0.000
lower average	863	0.17	*0.28*	271	0, 14	*0.24*	0.056	0.000
high school	1695	0.33	*0.61*	526	0.27	*0.51*	0.245	0.026
Bachelor's degree	1212	0.23	*0.84*	459	0.24	*0.75*	0.295	0.090
Master's degree	821	0.16	*1,00*	476	0.25	*1.00*	0.277	0.000
Total	5191	1		1917			0.884 ***0.116***	***0.116***

Bold values indicate the final results of concentration index for the three scenarios

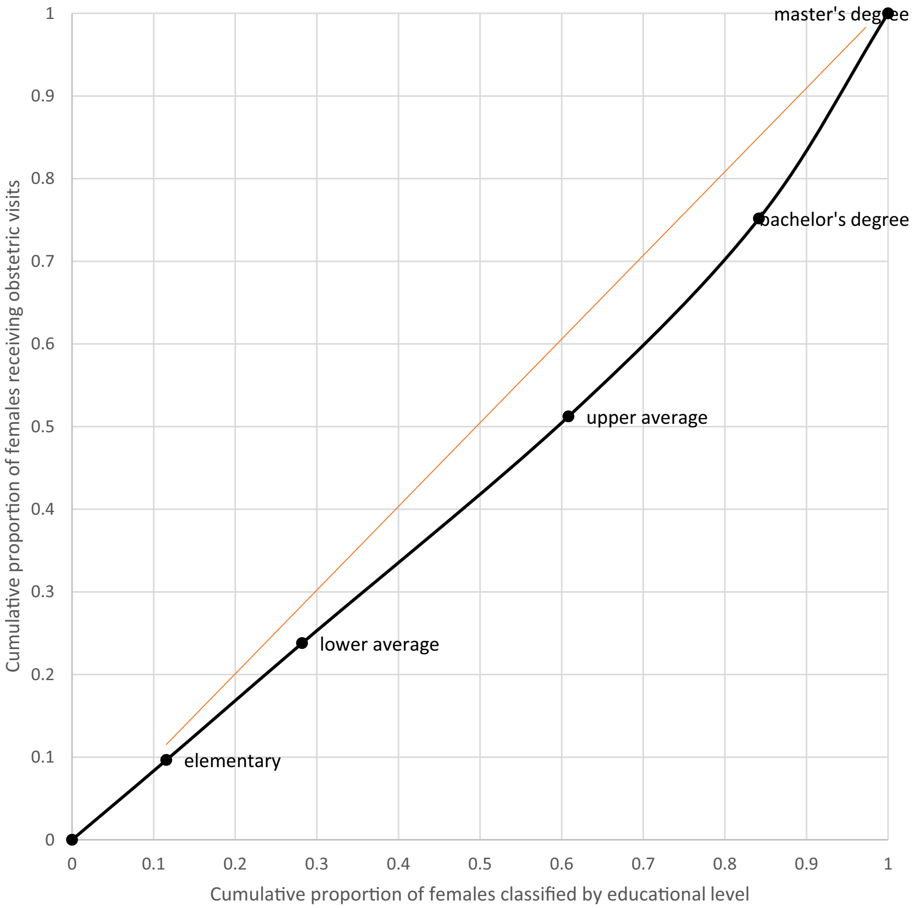


Fig. 6 Curve of concentration of obstetric needs as a function of education level

In summary, highly educated females are more likely to get obstetric care from qualified personnel.

4.2 Scenario Two: Calculation of the Infant Mortality Rate Indices in the Italian Regions Classified According to per Capita Income

This application calculates the KI, the SII and the CI on the 20 Italian regions ordered by per capita income, using the official statistical sources of the Institute National Statistics (ISTAT) for the year 2016. The surveyed population is represented by the number of live births, while the social and health variable was identified in the number of infant deaths.

4.2.1 Calculation of the Kuznets index on the infant mortality rate of the Italian regions

Table 6 presents the procedure for calculating the Kuznets index and the SII and for producing the relative graphs (Figs. 7, 8).

The value of the absolute Kuznets index is given by the difference between the percentage value of infant deaths in the most advantaged quintile (0.26%) and the most disadvantaged (0.36%). Its value is −0.10%. The relative Kuznets index is instead given by

Table 6 Regions, Per capita income, infant mortality rate, live births, infant deaths, proportion of live births, proportion of infant deaths (*Source*: Health for all)

Region	Per capita income (2016)	Live births F_n	f_{rn}	f_{rn} *cum*	Child deaths F_d	*% infant deaths*
Calabria	€ 12,514	15,959	0.03	*0.03*	77	*0.48%*
Campania	€ 13,262	49,431	0.11	*0.14*	158	*0.32%*
Sicily	€ 13,280	41,390	0.09	*0.23*	164	*0.40%*
Basilicata	€ 13,707	3,963	0.01	*0.24*	17	*0.42%*
Puglia	€ 13,977	30,668	0.07	*0.30*	84	*0.27%*
Molise	€ 14,155	1,764	0.00	*0.31*	2	*0.10%*
Sardinia	€ 15,167	10,448	0,02	*0.33*	27	*0.26%*
Abruzzo	€ 15.984	9,924	0.02	*0.35*	25	*0.25%*
Umbria	€ 18.104	5,453	0.01	*0.36*	9	*0.17%*
Marche	€ 18.661	11,107	0.02	*0.39*	21	*0.19%*
Lazio	€ 19,469	46,528	0.10	*0.49*	131	*0,28%*
Tuscany	€ 20,143	26,317	0.06	*0.54*	70	*0.27%*
Veneto	€ 20,284	37,975	0.08	*0.62*	88	*0.23%*
Friuli-Venezia Giulia	€ 20,577	8,526	0.02	*0.64*	17	*0.20%*
Piedmont	€ 20,634	31,504	0.07	*0.71*	70	*0.22%*
Valle d'Aosta	€ 21,181	906	0.00	*0.71*	4	*0.42%*
Liguria	€ 21,359	9,898	0.02	*0.73*	25	*0.25%*
Emilia –Romagna	€22,521	34,388	0.07	*0.81*	70	*0.20%*
Lombardy	€ 22,529	79,546	0.17	*0.98*	220	*0.28%*
Trentino-Alto Adige	€ 23,279	9,896	0.02	*1.00*	32	*0.33%*
Total		465,591			1311	

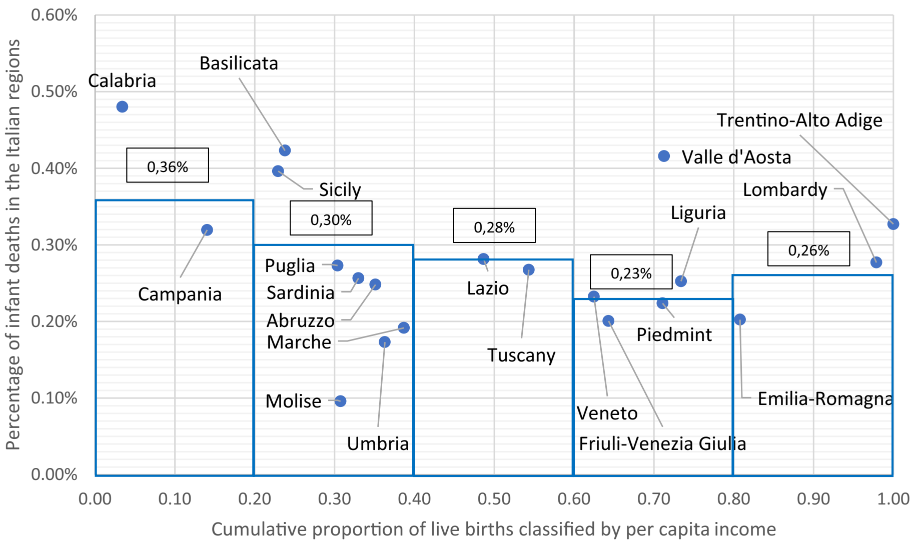


Fig. 7 Kuznets index for infant deaths as a function of per capita income

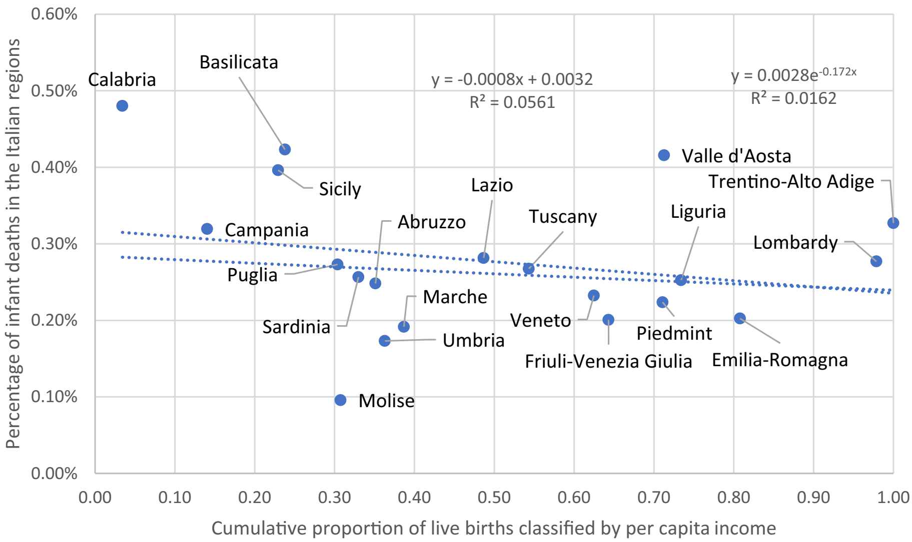


Fig. 8 Incline index of inequalities for infant deaths as a function of per capita income

0.26%/0.36% = 0.72. This can be interpreted by stating that children born in regions with lower per capita income have an excess of 0.10% infant mortality compared to those born in more privileged regions. Conversely, the relative index points out that children born in the most advantaged regions have a 0.72 times lower risk of incurring an infant death than residents of less privileged regions.

4.2.2 Calculation of the SII on the infant mortality rate of the Italian regions

The phases for calculating the SII followed this order: first a point diagram is presented, placing the cumulative proportion of live births on the ordinate axis and the percentage of infant deaths in the individual regions on the abscissa axis. From the trend of the scatter, secondly, it is possible to calculate the relative regression line, which is identified as follows: $y = -0.0008x + 0.0032$.

The SII obtained in this second analysis is given by the difference between 0.24 and 0.32%, an SII of −0.08% is obtained.

The SII value can be interpreted by noting that those born in regions with the highest per capita income are 0.08% less likely to incur infant death than those born in low-income regions.

4.2.3 Calculation of the CI on the infant mortality rate of the Italian regions through the Brown and the Fuller and Lury formulas

Table 7 presents the procedure for calculating the CI and for the related graphical representation.

Also, in this case the two columns in italic in the table are used for the calculation of the CI and to construct the concentration curve (see Fig. 9).

The calculation of the CI, which in this analysis leads to a result of −0.073, indicates the existence of a weak inequality which is favourable to the population with higher per capita income.

All indices have extremely low values, and this leads us to conclude that inequalities in income have no relevant relationship with the inequalities found in the infant mortality rate.

4.3 Scenario Three: Calculation of the Indices on the Rate of People Who Declare to Have Poor Health in the Italian Regions Classified Based on per Capita GDP

In this further analysis, the KI, the SII and the CI have been calculated on the 20 Italian regions ordered by GDP per capita, using the data sources produced by ISTAT for the year 2017. The population under investigation is represented by residents, while the social and health variable is the number of people who declared a bad or very bad state of health in the multipurpose survey.

4.3.1 Calculation of the Kuznets index on the rate of people in poor health in the Italian regions

Table 8 presents the procedure for calculating the Kuznets index and the SII, also useful for the related graphic displays (Figs. 10, 11).

The value of the absolute Kuznets index is given by the difference between the percentage value of people reporting ill health in the most advantaged quintile (5.55%) and the most disadvantaged (10.22%), reaching a value equal to −4.67%. The value of the relative Kuznets index is instead given by 5.55%/10.22% = 0.54. The values obtained for these indices can be interpreted as follows: residents in the most disadvantaged regions have an excess of 4.67% of those who declare ill health compared to residents who live in the most

Table 7 Cumulative proportion of births alive, cumulative proportion of infant deaths and steps for calculating the concentration index

Region	Per capita income (2016)	Live births F_n	f_{rn}	f_{rn} *cum*	Infant deaths F_d	f_{dr}	f_{dr} *cum*	Brown	Fuller e Lury
Calabria	€ 12,514	15,959	0.03	*0.03*	77	0.06	*0.06*	0.002	−0.002
Campania	€13,262	49,431	0.11	*0.14*	158	0.12	*0.18*	0.025	0.002
Sicily	€13,280	41,390	0.09	*0.23*	164	0.13	*0,30*	0.043	0.000
Basilicata	€ 13,707	3,963	0.01	*0.24*	17	0.01	*0.32*	0.005	−0.006
Puglia	€ 13,977	30,668	0.07	*0.30*	84	0.06	*0.38*	0.046	−0.001
Molise	€ 14,155	1,764	0, 00	*0.31*	2	0.00	*0.38*	0.003	−0.002
Sardinia	€15,167	10,448	0.02	*0.33*	27	0.02	*0.40*	0.018	−0.002
Abruzzo	€ 15,984	9,924	0.02	*0.35*	25	0.02	*0, 42*	0.018	−0.002
Umbria	€ 18,104	5,453	0.01	*0.36*	9	0.01	*0.43*	0.010	−0.004
Marche	€ 18,661	11,107	0.02	*0.39*	21	0.02	*0.44*	0.021	−0.006
Lazio	€ 19,469	46,528	0.10	*0.49*	131	0,10	*0.54*	0.099	−0.005
Tuscany	€20,143	26,317	0.06	*0.54*	70	0.05	*0.60*	0.065	−0.012
Veneto	€ 20,284	37,975	0.08	*0.62*	88	0.07	*0.67*	0.103	−0.004
Friuli-Venezia Giulia	€20,577	8,526	0.02	*0.64*	17	0.01	*0.68*	0.025	−0.011
Piedmont	€ 20,634	31,504	0.07	*0.71*	70	0.05	*0.73*	0.095	0.001
Valle d’Aosta	€ 21,181	906	0.00	*0.71*	4	0.00	*0.74*	0.003	−0.002
Liguria	€ 21,359	9,898	0.02	*0.73*	25	0.02	*0.75*	0.032	−0.017
Emilia-Romagna	€22,521	34,388	0.07	*0.81*	70	0.05	*0,81*	0.115	−0.002
Lombardy	€ 22,529	79,546	0.17	*0.98*	220	0.17	*0.98*	0.305	0.003
Trentino-Alto Adige	€ 23,279	9,896	0.02	*1.00*	32	0.02	*1.00*	0.042	0.000
Total		465,591	1		1311	1		1.073 − **0.073**	−***0.073***

Bold values indicate the final results of concentration index for the three scenarios

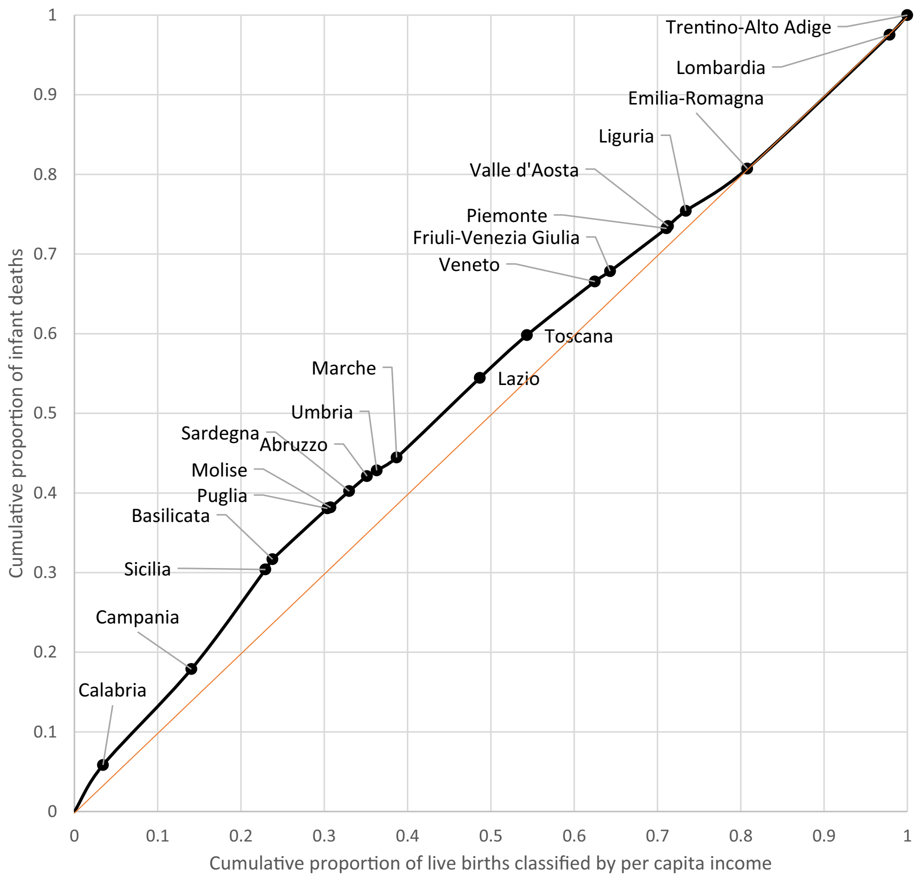


Fig. 9 Concentration curve of infant deaths as a function of per capita income

privileged regions. Furthermore, for the relative index, it can be easily stated that those living in the most advantaged regions have a 0.54 times lower risk of declaring ill health than residents of less privileged regions.

4.3.2 Calculation of the SII on the rate of people in poor health in the Italian regions

The regression line in this analysis can be expressed through the equation: $y = -0.0513x + 0.0936$ while a better fit is obtained through the exponential model equation $y = 0.0956e^{-0749x}$.

The SII calculated on the line is equal to −5.13%, obtained from the difference between 4.23 and 9.36%.

Instead, the one obtained from the exponential curve is equal to −5.04% (4.52–9.56%).

From the value of the SII it can be said that those who reside in regions with lower per capita GDP have an excess of individuals who declare a state of ill health of 5.13% in the linear model (or 5.04% in the exponential model) compared to those who live in regions with the highest per capita GDP.

Table 8 Regions, GDP per capita, resident population, people in poor health (Source: Health for all)

Region	GDP per capita (2017)	Resident population F_p	f_{pn}	f_{pn} *cum*	People in poor health F_c	*% people in poor health*
Calabria	17,100 €	1,929,677	0.03	*0.03*	208,019	*0.11*
Sicily	17,400 €	4,960,044	0.08	*0.12*	496,004	*0.10*
Campania	18,200 €	5,769,772	0.10	*0.21*	436,772	*0.08*
Puglia	19,000 €	4,012,517	0.07	*0.28*	207,447	*0.05*
Molise	19,500 €	307,482	0.01	*0.28*	19,771	*0.06*
Basilicata	20,800€	564,687	0.01	*0.29*	44,215	*0.08*
Sardinia	21,300 €	1,281,649	0.02	*0.32*	122,269	*0.10*
Umbria	24,300 €	878,735	0.01	*0.33*	86,116	*0.10*
Abruzzo	24,400 €	1,309,995	0.02	*0.35*	89,866	*0.07*
Marche	26,600 €	1,529,396	0.03	*0.38*	91,458	*0.06*
Liguria	29.678 €	1,546,460	0.03	*0.40*	114,438	*0.07*
Piedmont	30,300 €	4,360,130	0.07	*0.48*	300,849	*0.07*
Tuscany	30,500 €	3,716,720	0.06	*0.54*	202,561	*0.05*
Friuli-Venezia Giulia	31,000 €	1,210,662	0.02	*0.56*	76,998	*0.06*
Lazio	32,900 €	5,774,349	0.10	*0.66*	355,700	*0.06*
Veneto	33,100 €	4,883,475	0.08	*0.74*	273,475	*0.06*
Valley d'Aosta	35,200 €	126,445	0.00	*0.74*	6499	*0.05*
Emilia-Romagna	35,300 €	4,442,844	0.07	*0.81*	288,341	*0.06*
Lombardy	38,200 €	9,978,691	0.17	*0.98*	531,864	*0.05*
Trentino-Alto Adige	39,200 €	1,066,236	0.02	*1.00*	39,451	*0.04*
Total		59,649,966	1		3,992,113	

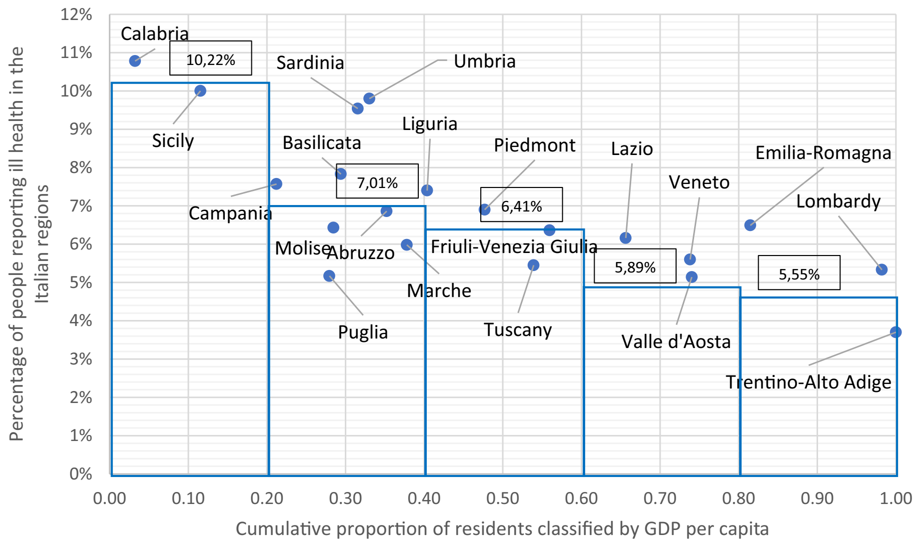


Fig. 10 Kuznets index for poor health registrants as a function of per capita GDP

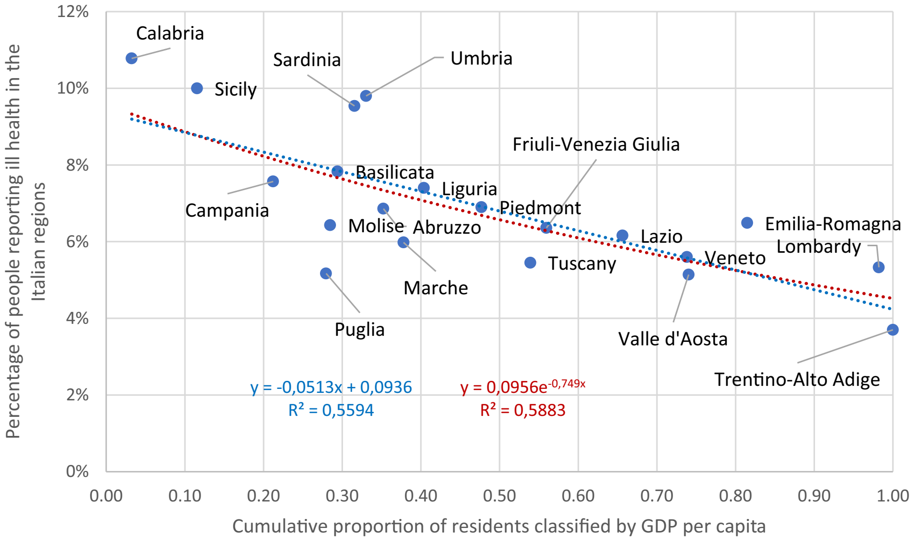


Fig. 11 Slope index of inequality for the registrants of ill health as a function of GDP per capita

4.3.3 Calculation of the CI on the rate of people in poor health in the Italian regions through the Brown and the Fuller and Lury formulas

The value of the CI obtained in this analysis of −0.125 shows a significant inequality which is favourable to the resident population in the regions with the highest per capita income. (Table 9).

5 Calculation of the CI According to Wagstaff and Van Doorslaer. An Application in the Context of the Marche Region

In this section we present the calculation of the CI at the regional level using the above formulas. The purpose is to highlight the temporal change in this index in the regional context.

We used data from the ISTAT "Multi-Purpose Family, Aspects of Daily Life" survey, which interviews a representative sample of about 20,000 families and 60,000 individuals residing in Italy. For this analysis we used data from 2005 to 2012 with specific reference to the Marche Region. Since there is no direct income indicator in the Multi-Purpose Survey, we used the Principal Component Analysis (ACP) method to create a one-dimensional socio-economic index consisting of a linear combination of the available variables, such as home ownership, presence of a domestic worker and a set of possessions: television, satellite dish, cell phone, computer, Internet access, hi-fi system, video camera, washing machine, dishwasher, air-conditioner, car, etc. (Vyas and Kumaranayake, 2006; Wagstaff et al., 2007). The income-related values are placed on the abscissa.

The cumulative percentage of people expressing a good or very good rating on their health is positioned on the ordinate axis. The indicator for perceived health was recoded in a binary variable (yes/no), to make the survey homogeneous. This strategy has been applied since in 2007 the way of detecting perceived health was changed by changing the

Table 9 Cumulative proportion of residents, cumulative proportion of registrants of ill health and steps for the calculation of the concentration index

Region	GDP per capita (2017)	Resident population F_p	f_{pn}	*f_{pn} cum*	People in poor health F_c	F_{cr}	*F_{cr} cum*	Brown	Fuller e Lury
Calabria	17,100 €	1,929,677	0.03	*0.03*	208,019	0.05	*0.05*	0.002	0.000
Sicily	17,400 €	4,960,044	0.08	*0.12*	496,004	0.12	*0.18*	0.019	−0.004
Campania	18,200 €	5,769,772	0.10	*0.21*	436,772	0.11	*0.29*	0.045	−0.008
Puglia	19,000 €	4,012 51,	0.07	*0.28*	207,447	0.05	*0.34*	0.042	0.000
Molise	19.500 €	307,482	0.01	*0.28*	19,771	0.00	*0.34*	0.004	0.000
Basilicata	20,800 €	564,687	0.01	*0.29*	44,215	0.01	*0.35*	0.007	0.001
Sardinia	21,300 €	1,281,649	0.02	*0.32*	122,269	0.03	*0.38*	0.016	0.001
Umbria	24,300 €	878,735	0.01	*0.33*	86,116	0.02	*0.41*	0.012	−0.001
Abruzzo	24,400 €	1,309,995	0.02	*0.35*	898 66	0.02	*0.43*	0.018	−0.003
Marche	26,600 €	1,529,396	0.03	*0.38*	91,458	0.02	*0.45*	0.023	−0.001
Liguria	29.678 €	1,546,460	0.03	*0.40*	114,438	0.03	*0, 48*	0.024	−0.005
Piedmont	30,300 €	4,360,130	0.07	*0.48*	300,849	0.08	*0.56*	0.076	−0.010
Tuscany	30,500 €	3,716,720	0.06	*0.54*	202,561	0.05	*0.61*	0.072	−0.002
Friuli-Venezia Giulia	31,000 €	1,210,662	0.02	*0.56*	76,998	0.02	*0.63*	0.025	−0.011
Lazio	32,900 €	5,774,349	0.10	*0.66*	355 700	0.09	*0.71*	0.130	−0.014
Veneto	33,100 €	4,883,475	0.08	*0.74*	273,475	0.07	*0.78*	0.123	0.000
Valle d'Aosta	35,200 €	126,445	0.00	*0.74*	6499	0.00	*0.78*	0.003	−0.005
Emilia-Romagna	35,300 €	4,442,844	0.07	*0.81*	288,341	0.07	*0.86*	0.122	−0.035
Lombardy	38,200 €	9,978,691	0.17	*0.98*	531,864	0.13	*0.99*	0.309	−0.008
Trentino-Alto Adige	39,200 €	1,066,236	0.02	*1.00*	39,451	0.01	*1.00*	0.036	0.000
Total		59,649,966	1		3,992,113	1		1.105 ***−0,105***	***−0.105***

Bold values indicate the final results of concentration index for the three scenarios

The two columns in italic in the table are used for the calculation of the *CI* and to construct the concentration curve (Fig. 12)

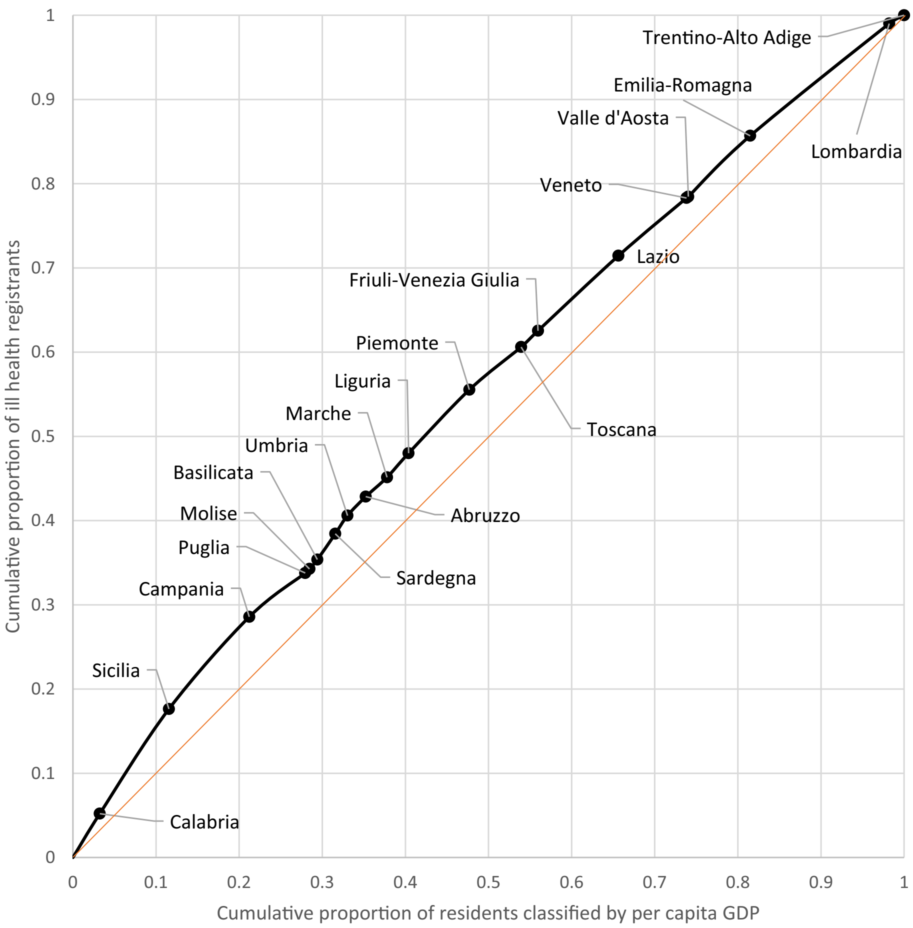


Fig. 12 Concentration curve of ill health registrants as a function of GDP per capita

value 3 from the judgement "fairly" to that of "neither good nor bad". Therefore, the binary variable obtained variable will assume the value 1, if the interviewee has expressed good or very good health, instead the value 0 if the interviewee has expressed a degree of judgment oscillating between "very bad" health, " bad "and" fairly "or" neither good or bad ", depending on the survey year, as indicated above. For this reason (use of a *limited dependent variable* distributed between 0 and 1) the CI was redefined with the correction proposed by Erreygers (2005, 2009).

The index values in Table 10 show a range between 0.207 in 2005 to 0.055 obtained in 2006, when considering only the significant values. Health good or very good is more likely in population groups with higher income. The values of CI, although not particularly high, do suggest some inequality and are significant except for the years 2008 and 2010.

A visualisation of values for 2011 and 2012 are exhibited in Fig. 13.

For aesthetic reasons we have limited the presentation of the concentration curves in the graph to the two most recent years.

Table 10 Concentration Indices of Perceived Health, from 2005 to 2012in the Marche region

	2005	2006	2007	2008	2009	2010	2011	2012
EDA index	0.207	0.055	0.088	0.006	0.097	0.047	0.076	0.115
P value	0.000	0.079	0.006	0.861	0.001	0.153	0.004	0.000
Standard error	0.024	0.031	0.031	0.036	0.028	0.033	0.026	0.030
Significance	***	*	**		**		**	***

The asterisks indicate the degree of statistical significance (* = 90%; ** = 95%; *** = 99%)

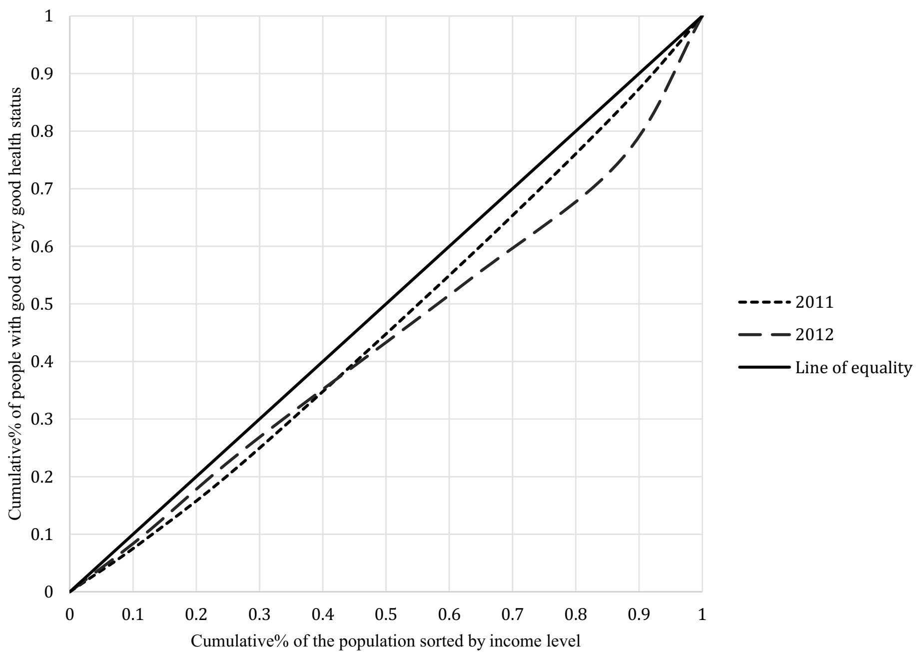


Fig. 13 concentration curves for the Marche region for the years 2011 and 2012

6 Conclusion

In this paper, after defining equity and underlying the importance of SDOH, we presented some conceptual models that allowed us to lay the foundations for measuring and monitoring inequalities. In fact, we developed a methodology that made it possible to describe and apply three important measures in Italian regions: the KI, the SII and the CI. The analysis of inequalities in the literature tends to choose only one approach at a time. Instead, our study compares different statistical methods, thus enhances the robustness of the findings, which are relatively insensitive to changes in the assumptions of the statistical models.

The measurement of health inequalities has its axiological basis in social determinants that are based on an eco-epidemiological and multilevel paradigm. It is essential to recognize that the study of inequalities is indispensable in promoting equity, a value in society and a guiding principle in the health policy agenda of governments.

The measurement strategies here recommended reflect what we think are desirable characteristics of the statistics because of the way they capture important dimensions of health inequality.

In synthesis, the analysis of the results allowed us to establish some key points.

First of all, as regards accessibility to obstetrics clinics by the female population classified by level of education, both the SII and the CI are consistent in their results, both showing a negative sign. This confirms that better educated population groups have a greater propensity to make preventive visits than less educated population groups. Consequently, a policy to improve the level of education will have positive repercussions on preventive policies and consequently on the health conditions of the female population (Cohen, 2013).

Furthermore, the analysis of infant mortality rates shows that the phenomenon has been almost eliminated in Italian regions. All this is consistent with the weak values assumed by the KI, the SII and the CI. In this case it can be said that per capita income has little influence on the phenomenon of infant mortality.

Finally, marked inequalities were observed in the analysis of self-declarations of perceived state of health in relation to GDP per capita. In this case the values of the three indices are consistent and high. This result confirms that declarations of ill health tend to be concentrated more in those Italian regions with a lower per capita GDP.

Our findings confirm the observation of others (Shawky, 2018; Mujica et al., 2019) that health inequalities are produced by social determinants of health.

The methodology adopted in this work obviously has some limitations, since it was applied only in regional contexts that had an adequate information system, such that allowed for its effective application. Therefore, its transferability over Italian local health authorities is desirable. In this case, a more specific and more detailed analysis would be obtained which would favour the activation and improvement of information systems existing today. In fact, health information systems are not currently designed to generate information on health inequalities or their association to the social root causes of ill health. Our research invites the health local authorities to activate a strengthening of the information systems to allow an easier application of the proposed methods. This would in turn enable diachronic and synchronic comparisons of the state of health of the populations and inequalities in their health care.

Another limitation is related to the impossibility of identifying confounding variables in the applications. For this reason, future studies could apply multivariate analysis, considering several SDOH variables simultaneously. This approach could lead to more detailed but also more difficult to interpret results.

The value of our analysis is to demonstrate that the above-mentioned methods could be used to help policy makers achieve their goals. In fact, in our application, we used available data and valuable, rigorous methods for decision-making. Moreover, the reduction of health inequalities will affect global policies that extend beyond health systems by acting on the SDOH. Furthermore, health inequalities have a significant economic impact. Therefore, their elimination or reduction represents a moral commitment that will have positive repercussions both on the national economy and on regional ones.

This type of research will also reinforce the link between statistical measurement and ethical considerations, both of which are instrumental in reducing and ultimately eliminating social inequalities in health.

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Declarations

Conflict of interest Authors have no conflicts of interest to declare that are relevant to the content of this article.

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